Image Cover Sheet

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TITLE

Fatigue Crack Initiation and Growth in A517 SAW Weldments Under Variable Amplitude Loading

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Fatigue Crack Initiation and Growth in A517 SAW Weldments Under Variable Amplitude Loading

by Christopher Bayley[1] and John Porter[2]

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ABSTRACT

A comparison between experimental and analytical predicted fatigue lives is made for a A517 SAW Weldment subjected to variable amplitude loading. Three, 10 inch wide butt-welded specimens were tested under a variable amplitude load spectrum consisting of 3 yearly storms. The magnitude of the loads in the storm increased and then decreased in a linear manner with the winter storm representing the most severe loading condition. Fatigue crack monitoring was achieved through the use of 20 localized potential drop probes affixed along the length of the weld. Multiple and independent fatigue crack initiation sites were found along the length of the weld. These eventually coalesced and formed a dominant fatigue crack, which led to the eventual failure of the specimens.

Fatigue life estimates using local notch strain and fracture mechanics approaches were obtained. Fatigue crack initiation life estimates using the strain life approach were found to be un-conservative while the estimates of the fatigue crack propagation life were conservative. Accurate knowledge of the structural and weld geometries was found to be critical in the estimation of the fatigue lives.

Fatigue Crack Initiation and Growth in A517 SAW Weldments

By: Christopher Bayley FTL
John Porter DREA
May 13 1999

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Objectives

- Effects of Variable Amplitude Load Spectrum on Fatigue Crack Initiation, Propagation and Coalescence
- Generate Experimental data on Fatigue Initiation and Propagation
- Compare Experimental and Numerical Fatigue Crack Predictions

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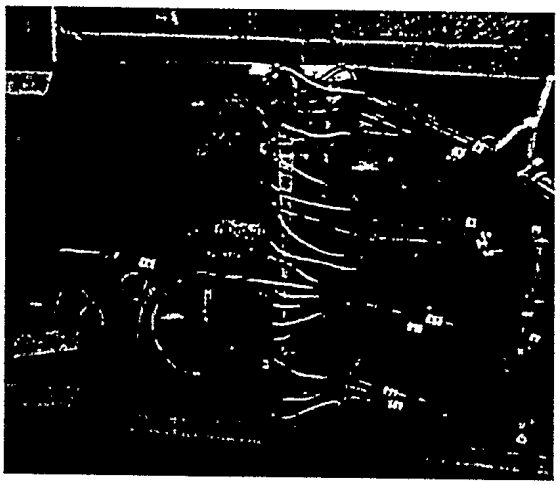
Experimental Work

- **Material Properties**
  - Cyclic Stress/Strain Curves
  - Fatigue Crack Initiation
  - Fatigue Crack Growth
- **Weld Residual Stresses**
- **Variable Amplitude Tests on 10" Wide Specimens**



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Material

- **10 mm A517 SAW Material Received from Dockyard Labs**
- **Representative of the Deck Material used in the Halifax Class Patrol Frigates**
- **Samples**
  - 6 Round Specimens
  - 3 Center Crack Panels
  - 3 10" Wide Specimens for VA Tests

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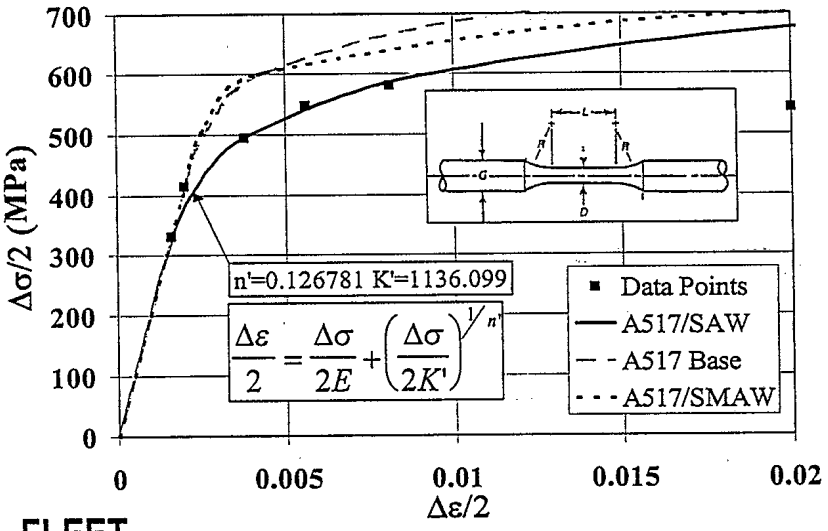
Material Properties
Cyclic Stress Strain Curve



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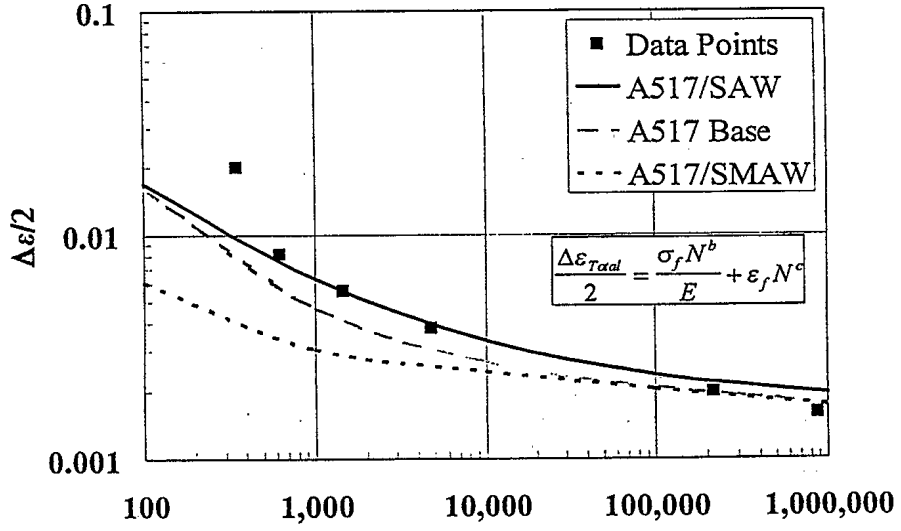
Material Properties
Fatigue Crack Initiation



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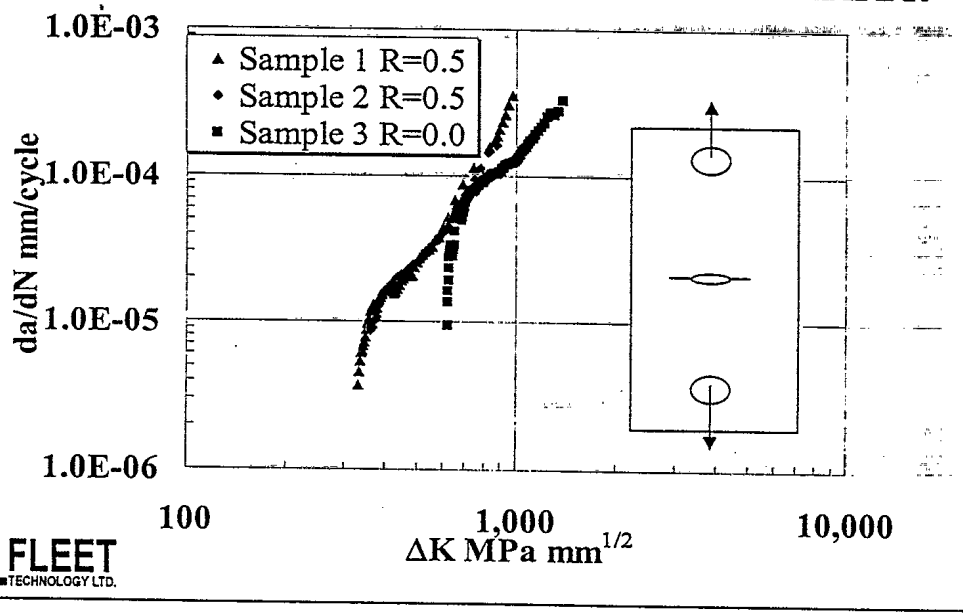
Material Properties
Fatigue Crack Growth



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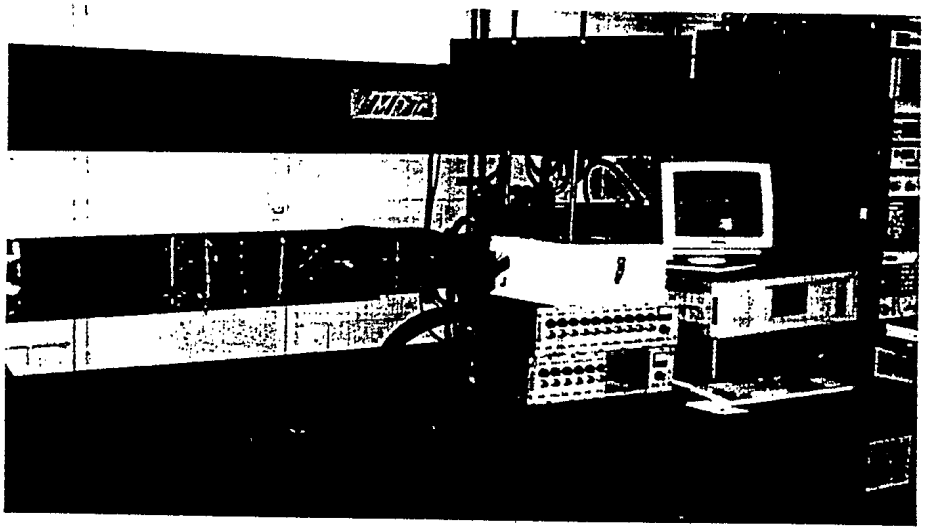
Variable Amplitude Tests
Fatigue Specimens



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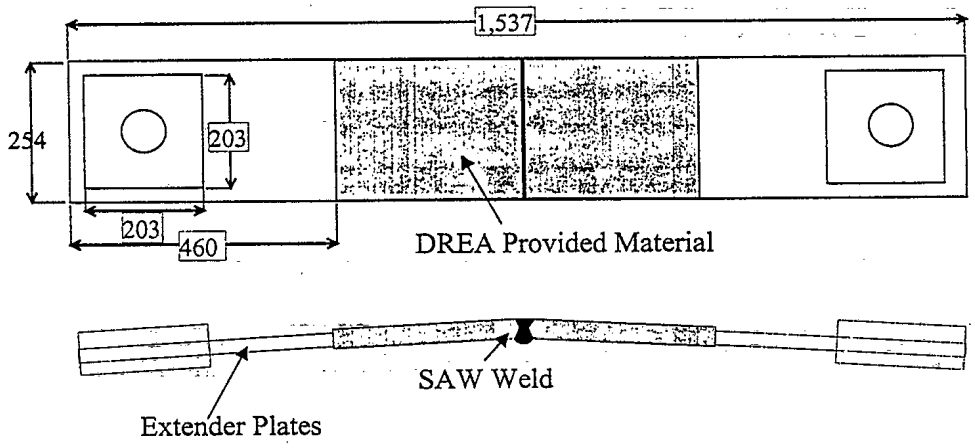
Specimen Characterization
Specimen Preparation



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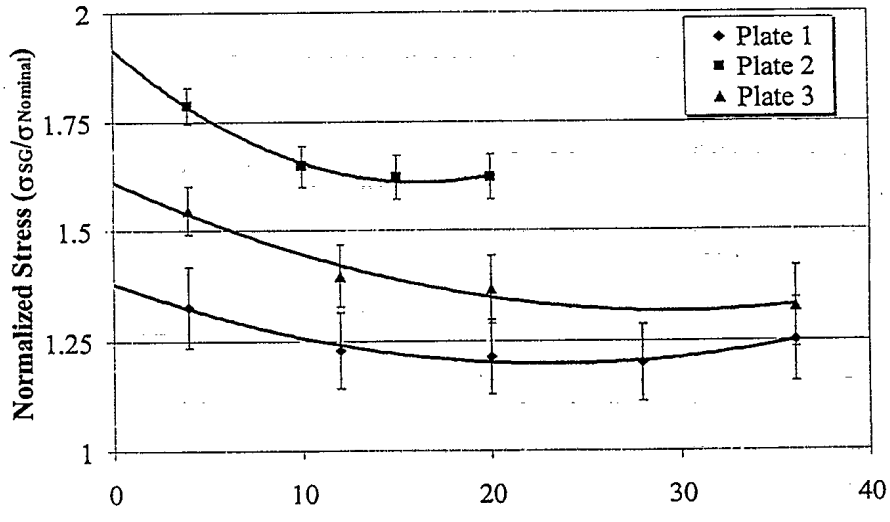
Specimen Characterization
Hot Spot Stress



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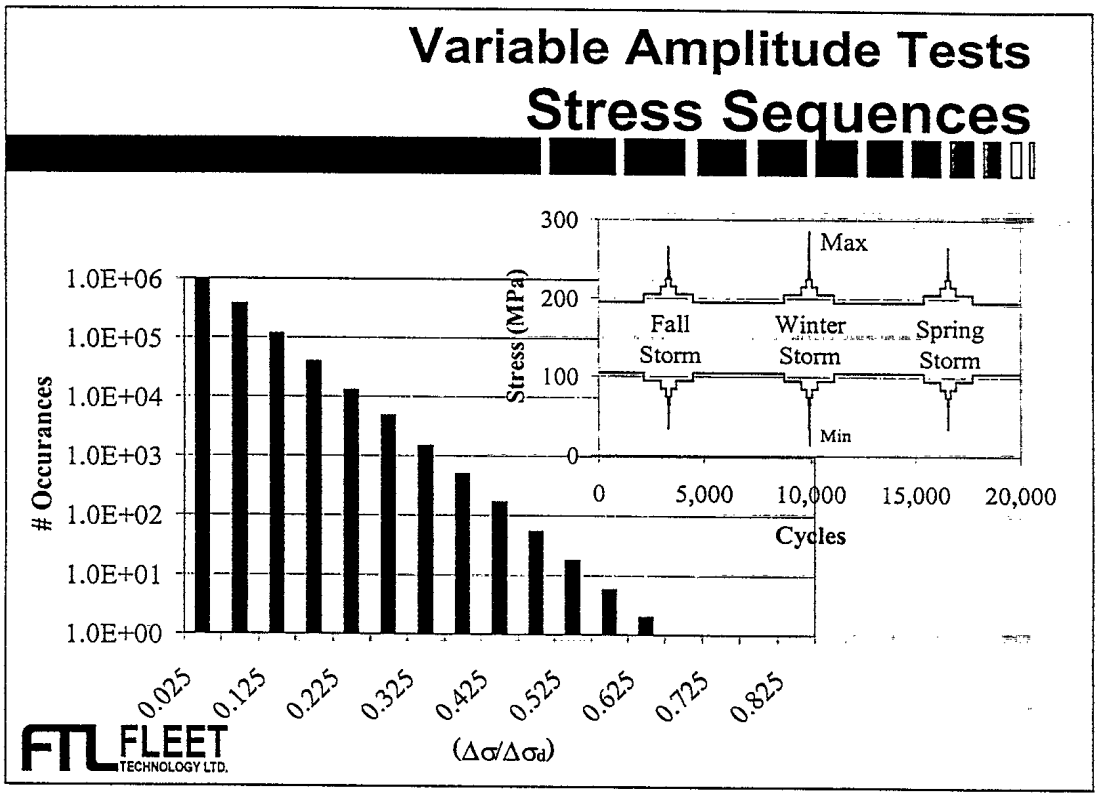
Variable Amplitude Tests
Stress Sequences
Occurances
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
0.025
0.125
0.225
0.325
0.425
0.525
0.625
0.725
0.825
(Δσ/Δσd)
Stress (MPa)
300
200
100
0
Max
Min
Fall Storm
Winter Storm
Spring Storm
0
5,000
10,000
15,000
20,000
Cycles
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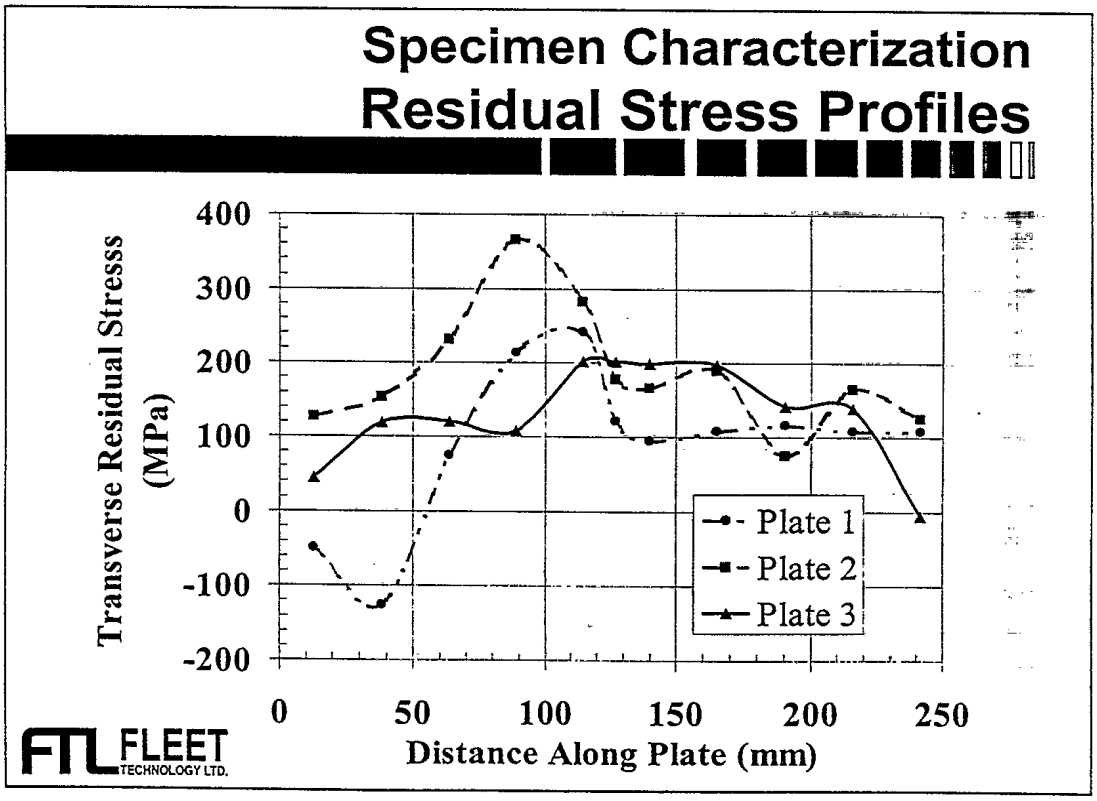
Specimen Characterization
Residual Stress Profiles
Transverse Residual Stresss (MPa)
400
300
200
100
0
-100
-200
0
50
100
150
200
250
Distance Along Plate (mm)
Plate 1
Plate 2
Plate 3
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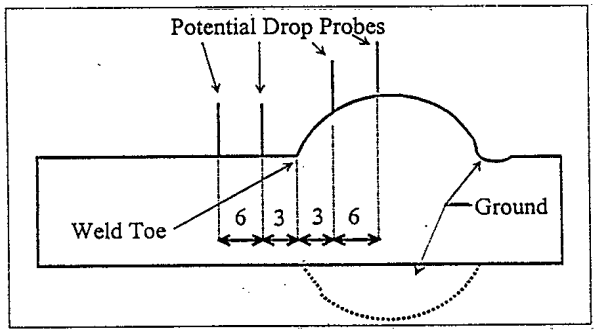
Variable Amplitude Tests
Crack Monitoring



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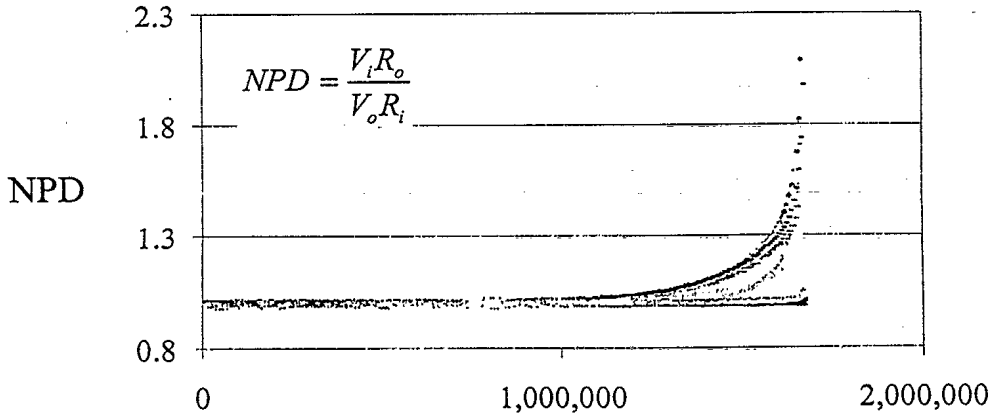
Variable Amplitude Tests
PD Time History



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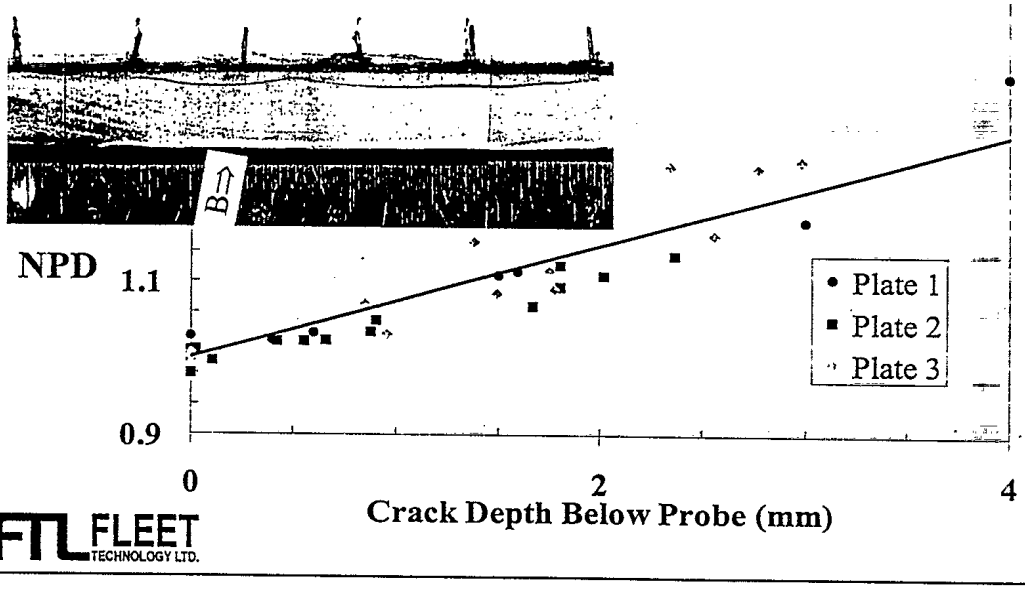
Variable Amplitude Tests
Beachmarks



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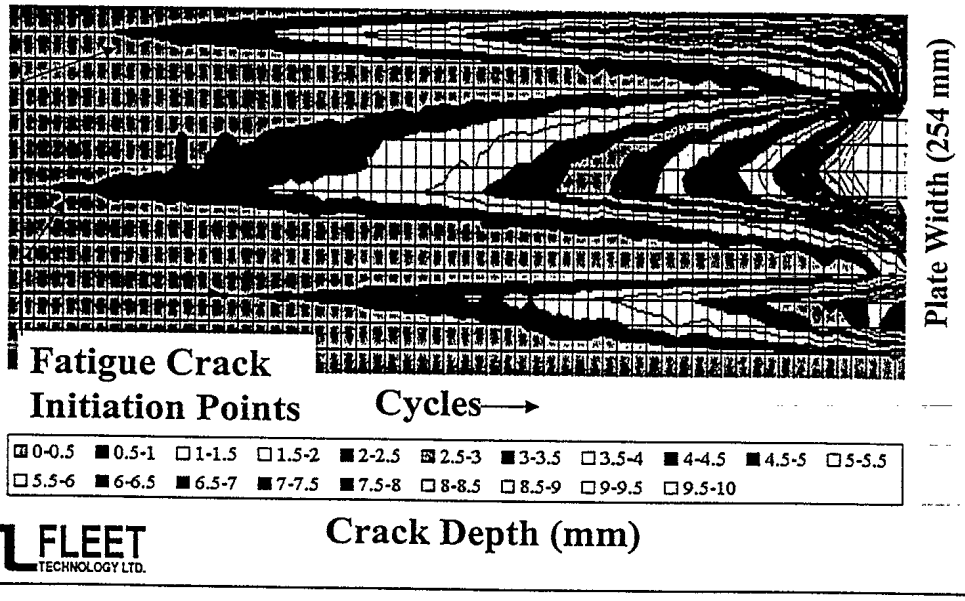
Variable Amplitude Tests
Fatigue Crack Initiation Sites



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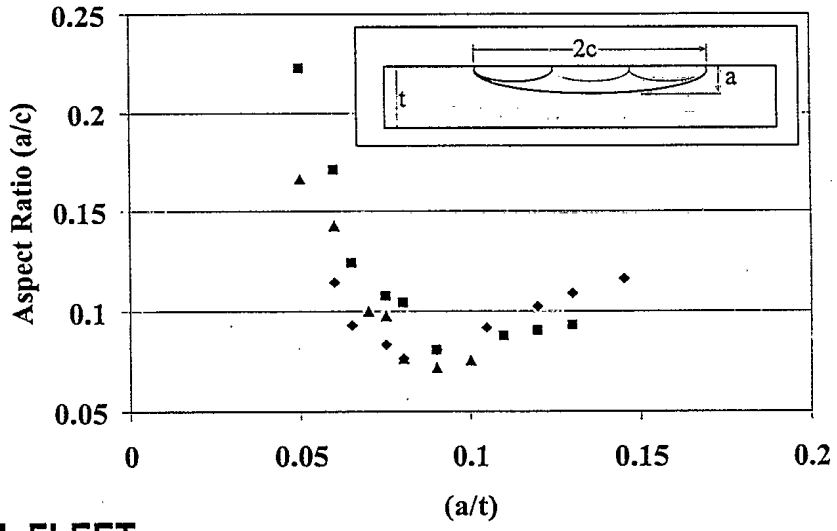
Variable Amplitude Tests
Crack Shape Development



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Analytical Approach

- Fatigue Crack Initiation and Propagation Software FALIN and FALPR
- Work Completed by: Dr Gregory Glinka University of Waterloo, Waterloo Ontario
- Stress Life (SN) Approach
- Strain Life (εN) Approach
- Fatigue Crack Growth (da/dN)

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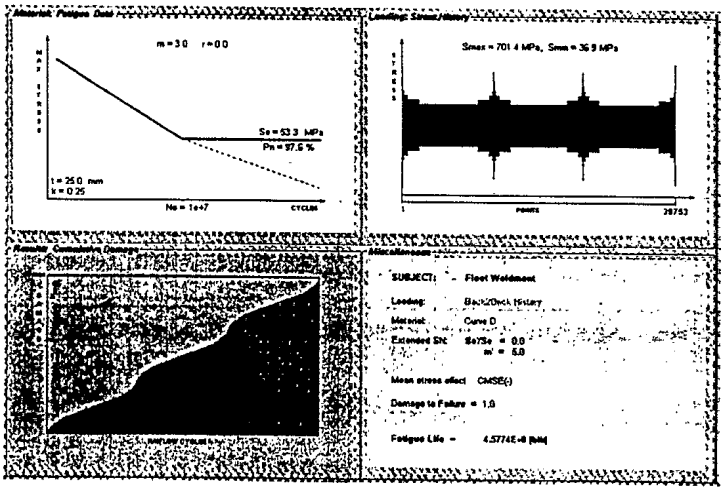
Analytical Approach
Stress Life



- BS-5400 'D' Detail Weld Transverse to Principle Stress dir.
- Miner's Summation used to sum damage from individual cycles
- Significant Damage Caused by Small Stress Ranges

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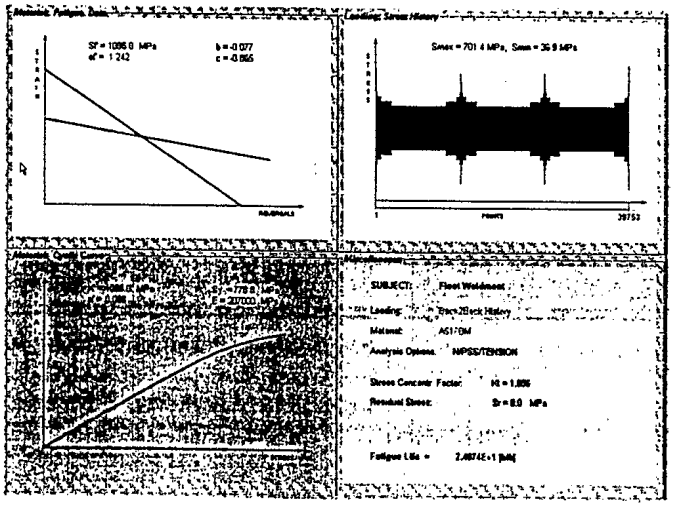
Analytical Approach
Strain Life



- Local Strain Approach accounts for:
- Geometry of the notch
- Angular Distortion and Straightening of Plates
- Membrane and Bending Components
- Residual Stress State
- Hot Spot Stress

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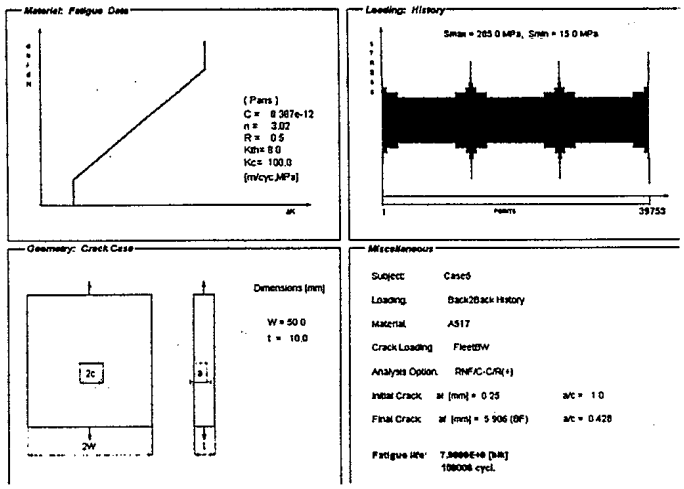
Analytical Approach
Fatigue Crack Growth



- Fatigue Crack Growth based on SIF and cycle by cycle integration
- Local Geometry affects included in SIF
- Model includes Variation in Membrane and Bending Stress
- FCR of a Single Semi-Elliptical Flaw

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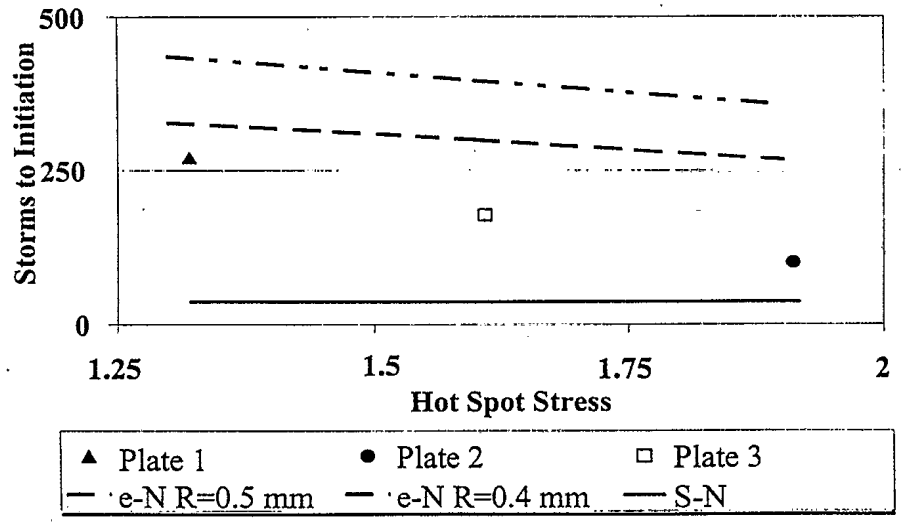
Results
Experimental & Numerical



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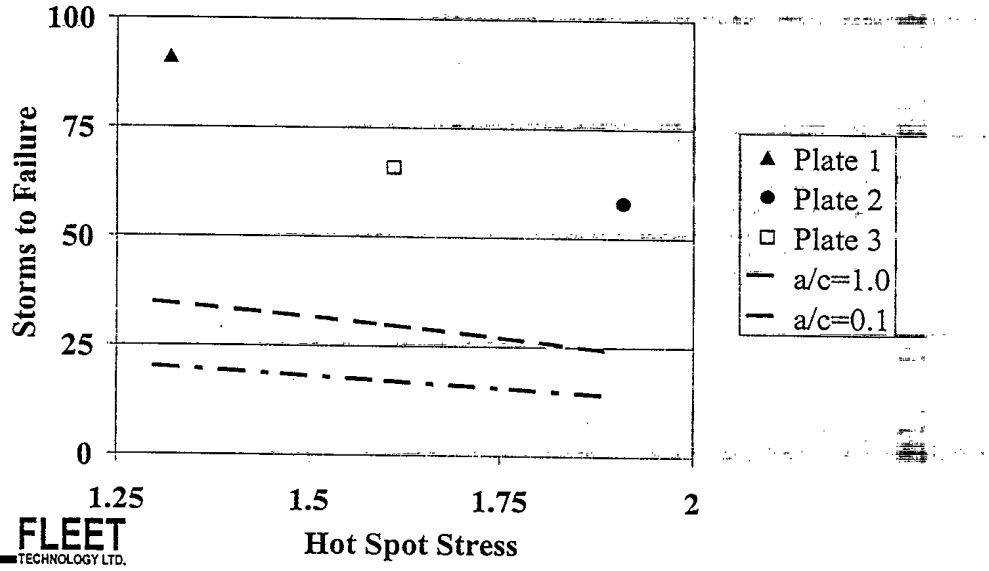
Results
Experimental & Numerical



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Conclusions
Numerical

- **S-N VERY Conservative**
- **ε-N Over-Predicts Fatigue Initiation**
  - Requires detailed information specific to each geometry
- **Fatigue Crack Growth**
  - Conservative if omit Retardation effects

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Conclusions
Experimental

- **Fatigue Crack Initiation accounts for 70% of Total Fatigue Life**
- **Variable Amplitude Loading affects the Number of Initiation Sites**
- **Fatigue Life Affected by:**
  - Hot Spot Stress Concentration
  - Notch Geometry
  - Angular Distortion of Specimens
  - Load Spectrum

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Recommendations
Future Research

- **Determine the influence of weld shape and residential strains on the fatigue performance of butt welded joints**
- **Variable and Constant Amplitude Tests**
- **Weld Toe Improvements and Fatigue Life**
- **Examine Agreement between Numerical Predictions and Experimental tests**

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